(12)

Report N00014-83-C-0728

A TIMING AND MEMORY SIZING STUDY FOR WAVENUMBER ANALYZER

Ralph W. Zaorski (Principal Investigator)
Jan Dolansky
Ben E. McCann

5 December 1983

Final Report for Period 1 Aug 1983 to 5 Dec 1983
Performed under Contract Number N00014-83-C-0728
DARPA Order Number 4462 Amendment 1

Prepared for

Office of Naval Research
Department of the Navy
800 N. Quincy Street
Arlington, Virginia 22217

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or the U.S. Government.

Dynatron Corporation

1345 Main Street Waltham, Massachusetts 02154 Telephone (617) 894-1512

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER N00014-83-C-0728	2. GOVT ACCESSION NO. AD-A135581	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Timing and Memory Sizing Study for WAVENUMBER ANALYZER		5. TYPE OF REPORT & PERIOD COVERED FINAL 83 Aug.01 to 83 Dec 15 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ralph W. Zaorski Jan Dolansky and Ben McCann		8. CONTRACT OR GRANT NUMBER(s) N00014-83-C-0728
9. PERFORMING ORGANIZATION NAME AND ADDRESS Dynatron Corporation 1345 Main Street Waltham, MA 02154		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARPA ORDER 4462 Amendment 1
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy, 800 N.Quincy S Arlington, VA 22217		12. REPORT DATE 5 Dec. 1983 13. NUMBER OF PAGES 36
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) UNCLASSIFIED - UNLIMITED DISTRIBUTION		DISTRIBUTION STATEMENT A Approved for public release; Distribution Unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) SPECTRAL ANALYSIS WAVENUMBER ANALYSIS		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

It is desired to perform frequency-wave number analysis on data from a P x Q element hydrophone array. It is assumed that the array may be mapped onto a plane, a sector of a sphere or a sector of a cylinder. A 3-dimensional frequency-wave number, averaged spectrogram is to be computed. The computation is to be performed using a VAX 11/780 mainframe computer in combination with an FPS AP-120B floating point array processor. All input,

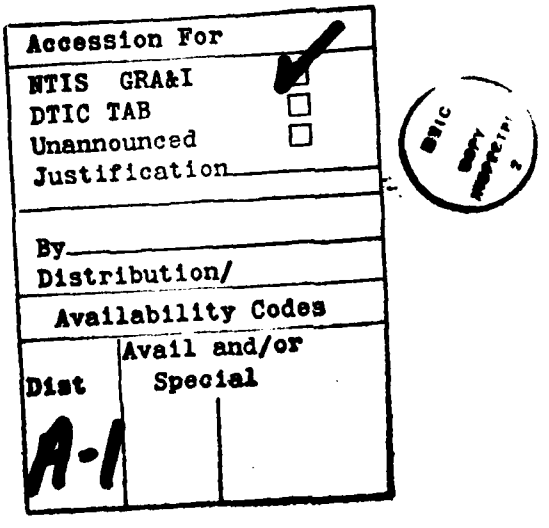
DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Continued from Block #20

output and intermediate data is to be stored on RP06 disk drives.

This report presents an evaluation of computation time, AP120B array processor memory requirements and disk storage requirements as a function of N=P x Q and M, the number of frequency cells to be analyzed. Equations are presented relating computation time and disk storage requirements to P, Q and M independently for both the terporal processing (time to frequency computation for each hydrophone waveform) and the spatial processing (2-dimensional wave number computation for each frequency cell selected). The equations have been evaluated using BASIC and the BASIC programs have been included along with representative results for selected values of P, Q and M.



SUMMARY

It is desired to perform frequency-wave number analysis on data from a PxQ element hydrophone array. It is assumed that the array may be mapped onto a plane, a sector of a sphere or a sector of a cylinder. A 3-dimensional frequency-wave number, averaged spectrogram is to be computed. The computation is to be performed using a VAX 11/780 mainframe computer in combination with an FPS AP-120B floating point array processor. All input, output and intermediate data is to be stored on RP06 disk drives.

This report presents an evaluation of computation time, AP120B array processor memory requirements and disk storage requirements as a function of N=PxQ and M, the number of frequency cells to be analyzed. The evaluation is based on a preliminary software design with the intent of obtaining "order of magnitude" sizing extimates. Equations are presented relating computation time and disk storage requirements to P, Q and M independently for both the temporal processing (time to frequency computation for each hydrophone waveform) and the spatial processing (2-dimensional wave number computation for each frequency cell selected). The equations have been evaluated using BASIC and the BASIC programs have been included along with representative results for selected values of P, Q and M.

The resulting times and memory requirements are presented in Appendix I for temporal processing and Appendix II for spatial processing. Various array configurations are considered (different values of P and Q). For Temporal processing M is taken as 4096. For Spatial processing, results are computed for M of 1024, 2048 and 4096. A summary of the results is presented below. The times given are for EACH iteration of the averaging process. The total time is the time given below times the number of computations averaged for each output point.

TEMPORAL PROCESSING

Hydrophones	Time (sec)	Disk Memory (Bytes)	AP120 Memory (Bytes)
36	10.7	2097150	49152
144	38.2	6291460	49152
256	62.0	8388610	49152
512	124.0	16777200	49152
1024	247.9	33554400	49152

SPATIAL PROCESSING

Phone in X	Phones in Y	Time (sec) 1024	2048	4096	Disk Mem (mBytes) 1024	2048	4096	AP120 (kBytes) 1024	2048	4096
6	6	100	200	401	2.10	4.19	8.39	1.28	1.28	1.28
12	12	214	427	854	8.39	16.8	33.6	5.12	5.12	5.12
16	16	249	497	995	8.39	16.8	33.6	5.12	5.12	5.12
16	32	447	894	1788	16.8	33.6	67.1	10.2	10.2	10.2
32	32	846	1691	3383	33.6	67.1	134	20.5	20.5	20.5

It is important to note that the primary consideration of this study is development of techniques for reducing the processing time. In particular, the major contributor to the processing time is disk reads and writes. This report describes an approach for organizing the data on the disk so that the disk read and write times can be minimized. Although significant time savings are achieved in this way, it is achieved at the expense of requiring special disk routines be written to achieve multiple record read and write from contiguous files.

1.0 Introduction

It is desired to perform frequency-wave number analysis on data from a PxQ element hydrophone array. It is assumed that the array may be mapped onto a plane, a sector of a sphere or a segment of a cylinder. An appropriate coordinate system will be chosen to permit the use of standard FFT analysis in all three dimensions (one temporal and two spatial). A 3-dimensional frequency-wave number, averaged spectrogram is to be computed. The computation is to be performed using a VAX 11/780 mainframe computer in combination with an FPS AP-120B floating point array processor. The VAX 11/780 has 3mBytes of RAM. It is assumed that 2.1mBytes may be assigned to data array storage. All input, output and intermediate data is to be stored on RP06 disk drives.

This report was prepared by Dynatron Corporation for the Office of Naval Research (ONR) under contract N00014-83-C-0728. It presents an evaluation of computation time and disk storage requirements as a function of N=PxQ and M, the number of frequency cells to be analyzed. The evaluation is based on a preliminary software design with the intent of obtaining "order of magnitude" sizing extimates. Equations are presented relating computation time and disk storage requirements to P, Q and M independently for both the temporal processing (time to frequency computation for each hydrophone waveform) and the spatial processing (2-dimensional wave number computation for each frequency cell selected). The equations have been evaluated using BASIC and the BASIC programs have been included along with representative results for selected values of P, Q and M.

The report is organized in the following way. Section 2 presents a brief description of the technique used to process the hydrophone data. The particular approach was devised by Dynatron as minimizing computation time and disk storage requirements. Section 3 provides the equations used to derive the computation times and disk storage requirements for both the temporal and spatial processing. Sample results and BASIC programs are presented in Appendices I and II. Appendix I addresses temporal processing and Appendix II addresses spatial processing.

2.0 Frequency-Wave Number Analysis Technique

This section presents a brief description of the processing technique recommended by Dynatron. In particular, a data reordering algorithm has been selected which minimizes the disk operations required to perform "corner turning" between the temporal and spatial processing steps.

The processing to be performed involves a "2-dimensional" PxQ element hydrophone array. The hydrophone array is mapped onto a plane, a sector of a sphere or a segment of a cylinder. Sampled time data from the array of N=PxQ hydrophones has been previously acquired and stored on disk. The data has been ordered into N files, with each file containing the total time history for a single hydrophone.

The analysis technique that will be considered here converts this data into a frequency-wave number spectrogram by the process shown in Figure 1 and outlined below.

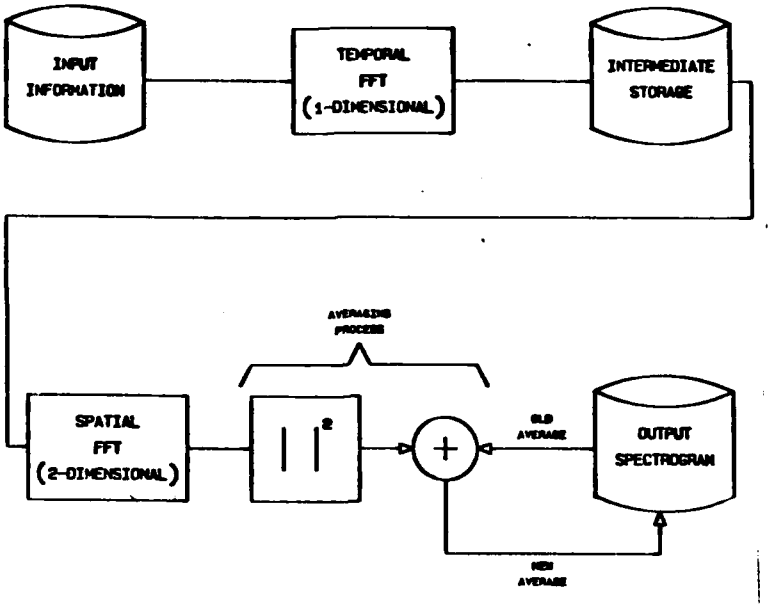


fig. 1

FREQUENCY WAVE NUMBER ANALYSIS

2.1 Temporal Processing

The first step in the computation process is conversion from real time samples into complex frequency data. Each hydrophone is processed independently.

1. 8192 time samples from each hydrophone file are read sequentially from disk into a buffer in memory. The time reference for each block of 8192 samples must be common across the array. If any sampling time skew is present, it is assumed to have been removed by appropriate interpolation as each of the data files for each hydrophone has been formed. Since data from only one hydrophone at a time is processed, all the hydrophone data may be accessed having only one file open at a time.

2. The 8192 samples from each hydrophone file are fed to an array processor, AP-120B, where the frequency spectrum is computed. The 8192 real samples are transformed into 4096 complex frequency samples (positive frequency). The time samples are windowed prior to FFT processing.

3. Frequency spectrum information is transferred back to memory where it is reordered to implement the first half of a corner turning operation. (see Fig. 2)

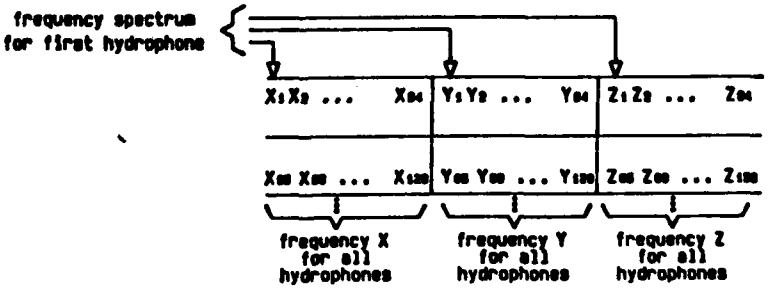


fig. 2 MEMORY MAP

4. The reordered data is written to disk in a contiguous fashion. Data written to disk comes from a 2,097,152 byte array in "core". Sectors on disk contain 512 bytes.

5. Steps 1-4 are repeated until all hydrophone data has been processed.

2.2 Spatial Processing

At this point a 2-dimensional Spatial FFT can be performed across the array for any frequency cell of interest. The processing performed is shown in Figure 2 and outlined below. It is important to note that all data to be spatially processed is read from disk. While the temporal transform operates on 8192 real data samples to produce 4096 complex frequency samples, the spatial transform will generally process fewer than the full 4096 frequency samples. For each frequency sample selected, the operations described below are performed.

1. Once the frequency cell has been selected, data is read off the disk into memory and the second half of the corner turning operation is performed. This time data is randomly accessed to obtain all data for that frequency cell. (see Fig. 3)

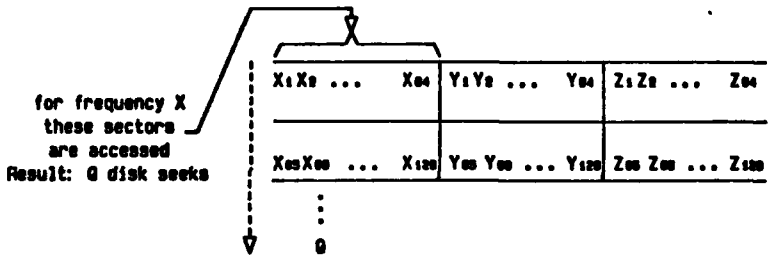


fig. 3 DISK MAP

2. The frequency information is then transferred from memory to the array processor, where the Spatial FFT is performed. Here the frequency information is loaded, occupying one quarter of the available array space. The remaining space is filled with zeroes. An FFT is performed along one axis, and then the other; as in Fig. 4. The wave number-frequency information is returned to memory.

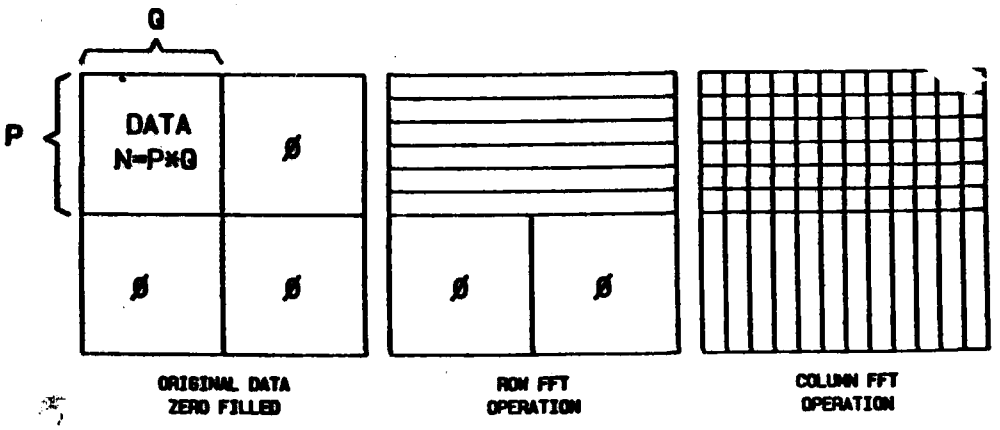


fig. 4 ARRAY MAP

3. The power is computed for each cell in wave number-frequency space and then averaged across similar computations performed for different time windows. The result is a 3-dimensional, averaged, wave number-frequency spectrogram.

3.0 Time Analysis of Wave Number Technique

This section is devoted to analyzing how long the frequency wave number analysis will take for different constraints. For ease of understanding the approach is divided into 2 parts and illustrated in Fig. 5. The first portion of the processing involves the computation of the Temporal FFT and includes these subgroups:

1. Read time data off disk.
2. Transfer data from memory to array processor.
3. Perform Temporal FFT.
4. Transfer data from array processor to memory and reorder data.
5. Write data from memory to disk.

The second portion of the processing involves the computation of the Spatial FFT which includes these subgroups:

1. Read data off disk, random access.
2. Transfer data from memory to the array processor.
3. Perform Spatial FFT.
4. Transfer data from the array processor to memory.
5. Averaging, read data off disk.
6. Averaging, computation time.
7. Averaging, write data to disk.

Additionally disk and AP-120B storage requirements are analyzed.

It is expected that there will be variations in the times and memory requirements computed in this section. In particular, when the processing is implemented, implementational trade-offs may result in more memory being used or more time expended. Such variations should be small.

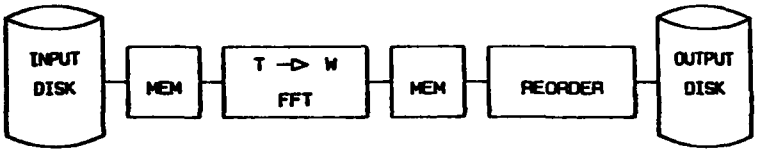


Fig. 5a Temporal FFT Processing

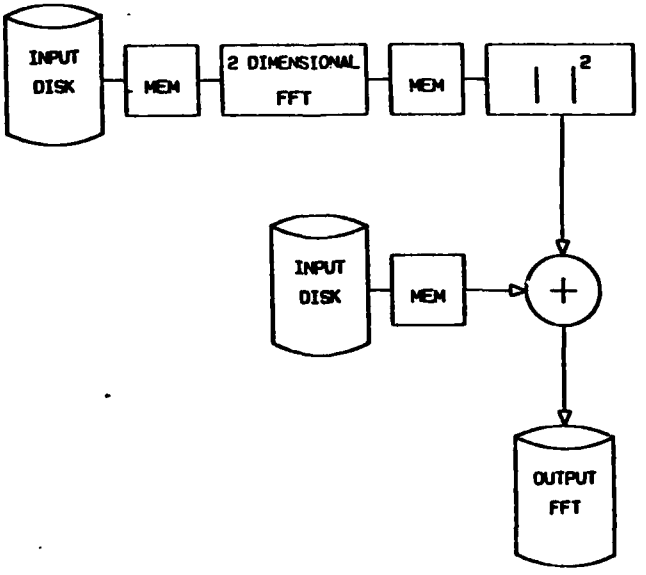


Fig. 5b Spatial FFT Processing

3.1 Temporal FFT Time Analysis Description

This section provides the reader with a detailed timing breakdown of the Temporal FFT process. For each step in the process an equation is shown describing the time involved. Temporal processing is performed one hydrophone at a time. The equations which follow compute the total time to perform the temporal processing for ALL hydrophones. The total time for the Temporal FFT process is the sum of all the steps. In addition section 3.1.6 describes disk space requirements for storing the results of the temporal processing, while 3.1.7 examines array processor storage requirements.

Selection of the number of time samples from each hydrophone to be processed will be made based on a tradeoff between the modal density and the interval over which the process remains quasi-stationary. Since it is assumed that there are 2,097,152 bytes of RAM in the VAX which can be used to assemble temporal FFT results, it is convenient to assume that the temporal FFT is performed on 8192 time samples. This choice, combined with the given disk sector size of 512 bytes, permits the temporal results to be sorted so that each frequency cell is assigned to a different block of 512 bytes, resulting in each frequency cell having its own assigned sector.

3.1.1 Read Time Data off Disk -

This section describes the time necessary to read a block of temporal data from disk. It is assumed that the temporal data from each hydrophone has already been "corner turned" and stored into a contiguous file on disk. The times which follow are also based on being able to read multiple contiguous records from a single track without expending additional rotational latency time. To achieve this, it will be necessary to write special disk routines which manipulate the disk controller appropriately to achieve this. FORTRAN I/O could be used with a commensurate time penalty. A decision on the type of I/O will be made when the detailed design is done.

The timing estimate below is based on the average seek time of 33ms. Worst case disk rotational time will be used. The worst case disk rotation time is 17ms. It is assumed that when reading or writing data to disk, a head switch can be achieved with no penalty but if a cylinder switch is required, it is necessary to loose one revolution.

$$A1 = N * ((H1 * R) + K3)$$

where: N = no. of hydrophones
R = Worst case disk rotational time (17ms)
K3 = Average seek time (33ms)
H1 = average number of rotations to transfer 16KB
(taken to be 1.52871)

3.1.2 Transfer data from memory to array processor -

This section describes the time it takes to transfer the 8192 time samples/hydrophone from memory to the array processor.

$$A2 = N * K7 / V$$

where: N = no. of hydrophones
K7 = no. bytes to transfer/hydrophone (16384)
V = data transfer rate from VAX to Array Processor

3.1.3 Perform Temporal FFT -

This section describes the time it takes the array processor to compute the Temporal FFT. This computation is divided into three sections.

a. Window: the data is multiplied by a window function already residing in the AP-120B. It is assumed that an arbitrary window function may be loaded once and used for all temporal computations.

b. FFT: the time to compute the 4096 point complex FFT. The 8192 time samples have been packed alternately into the real and imaginary words of the FFT input buffer.

c. Real FFT Step: a cleanup operation to produce the final positive w portion of the transform from the results of step (b) above.

$$A3 = N * T1 * M / 2 \quad \text{(Window)}$$
$$+ N * T1 * M * \log(M) / 2 \quad \text{(FFT)}$$
$$+ N * T1 * M / 2 \quad \text{(Real FFT Step)}$$

where: N = no. hydrophones
T1 = time/point/pass (taken at 1.46 us)
M = no. of FFT cells (4096)

and where log () is log base 2.

3.1.4 Transfer Data from Array Processor to Memory and Reorder Data -

This section describes the time required to transfer the frequency output information from the AP-120B back to buffer storage in main memory. The type of data to be transferred is floating point. In addition to the transfer operation, the data must be reordered as shown in fig. 2. This step requires a small loop which takes each datum as it is recieved and determines the position it will assume in memory. One iteration of this loop is accounted for in "L" and an example of such a loop is given.

A4 = N * (K8 / V + K9 * L)

where: N = no. hydrophones
K8 = no. bytes to transfer/hydrophone (32768)
V = array processor to VAX transfer rate
K9 = no. words to sort/hydrophone (K9=K8/4)
L = time to sort one word of data

```
Ex.   LOOP    MOVE.L    (ADDR1)+,(ADDR2)
              ADD.L     #512,ADDR2
              DEC       D1
              BNE       LOOP
```

Here: ADDR1= address of input information
ADDR2= address of output information
D1= counter (no. of input data left to transfer)

3.1.5 Write Data from Memory to Disk -

This section describes the time it takes to copy frequency information from buffer memory to disk. This operation is performed once for ever 64 operations of section 3.1.1-3.1.4. The total buffer length is 2,097,152 bytes or 186.18 full tracks of data. As above, it is assumed that the temporal processing re-

sults in 4096 frequency cells as output. To facilitate proper addressing of the records during the read phase of the corner turning between temporal and spatial processing, a full 2,097,152 byte buffer will always be transferred to disk, independent of the amount of the buffer actually filled. The number of these buffers necessary to represent all the data is calculated and indicated by Y1 below.

To achieve maximum efficiency for the transfer, it will be necessary to write some special routines which permit direct write of a portion of a block of data to a full track on disk. If this is done and if the data is stored in a contiguous file on disk, the worst case transfer time will be two disk rotations per track, since one disk rotation will be lost every time the heads are positioned to the next track. In addition, for each buffer transferred, it is necessary to perform a random seek operation. The time required by the operating system to set up each record transfer is also considered. The total transfer time is given below. For ease of understanding, use is made of intermediate variables Y1, Y2, Y3, and Y4.

```
Y1 = (INT ((N - 1) * M * K2 / S) + 1)     (no. buffers)
Y2 = S / (Q1 * X)                         (no. tracks/buffer)
Y3 = INT (Y1 * Y2 / H2)            (no. Cylinder boundaries)
Y4 = Y1 * (S / K8)                 (no. of disk transfer setups)

A5 = Y1 * Y2 * R       (Raw data transfer time, all buffers)
   + Y3 * R            (time for all cylinder changes)
   + K3 * Y1           (time to perform initial seek, for
                        all writes)
   + Y4 * R            (time for OS to set up transfer, for
                        all writes)
```

where: X = no. bytes/sector, taken to be 512
K2 = no. bytes/FFT Frequency cell
R = Time for one disk rotation
M = no. of spectral points
N = no. of hydrophones
Q1 = no. sectors/track (22)
S = no. bytes in buffer (2097152)
K3 = Average seek time (33 ms)
K8 = record size (32768)
H2 = no. tracks/cylinder

3.1.6 Disk Space Requirements -

This section describes the disk space required for the Temporal FFT procedure. This calculation considers only the storage used as a result of the Temporal FFT process; it does not include the initial hydrophone data. The result is an integeral number of buffers, represented in bytes, where each buffer is 2097152 bytes long.

```
B1 = (INT(((N - 1) * M * K2 ) / S ) + 1) * S
```

where: N = no. of hydrophones
M = no. of spectral points (4096)
K2 = no. of bytes/FFT cell (8)
S = no. of bytes in VAX buffer (2097152)

3.1.7 Array Processor Storage Requirements -

This section describes the storage space required in the AP-120B. The storage requirement is only that required for the temporal data from one hydrophone plus that required to store the window function. The storage will vary as the number of time samples/hydrophone examined varies. The result is in bytes.

```
S1 = N1 * 4     (output frequency data, floating point)
   + N1 * 2     (Window)
```

where: N1 = no. of time samples/hydrophone.

3.2 Spatial FFT Time Analysis Description.

This section presents a detailed breakdown of the time required for the Spatial FFT process. Each part describes the amount of time necessary to implement that piece of the process. Although each 2-dimensional FFT is calculated independently for each frequency cell selected from the temporal transform, these equations reflect the time required for all iterations of that step in the process based on the number of frequency cells which are analyzed. It is assumed however that as much time is required to perform a 12 x 12 FFT as is required for the 16 x 16. The array processor performs FFTs quickly that are multiples of 2. For this reason in all of the following calculations, P and Q (the hydrophone array dimensions) are rounded up to the next

higher power of 2. The total time required for the Spatial FFT process is the sum of all the steps. In addition section 3.2.8 describes disk space requirements for storing averaged data while 3.2.9 describes array processor space requirements.

3.2.1 Read Frequency Data off Disk, Random Access. -

This section describes the time required to read all information pertaining to a particular frequency cell for all hydrophones off disk and store it in buffer memory, as shown in fig. 3. This step completes the corner turning operation and will require disk sectors to be accessed randomly. Here 'INT ((N - 1) * K2 / X) + 1' represents the integral number of sectors occupied per frequency cell. This expression is used in many of the computations that follow.

$$B = M * (INT ((N - 1) * K2 / X) + 1) * (K3 + R / Q1)$$

where: M = no. of spectral points processed
N = no. of hydrophones
X = no. of bytes/sector
K2 = no. bytes/FFT cell
K3 = average seek time
Q1 = no. sectors/track
R = time for one disk rotation

3.2.2 Transfer Data from Memory to Array Processor -

This section describes the time it will take to transfer frequency cell information for all hydrophones from buffer memory to the AP-120B.

$$C = M * N * K2 / V$$

where: M = no. of spectral points
N = no. of hydrophones
K2 = no. bytes/FFT cell
V = data transfer rate VAX to array processor

3.2.3 Perform Spatial FFT -

This section describes the time it takes the array processor to compute the Spatial FFT. This computation is divided into three sections. (see Section 2.2, Fig. 4) For practical

purposes that concern the AP-120B, it is assumed that a 12 x 12 FFT will occupy a 16 x 16 area in the AP-120B and that it will require the same time for computation as the 16 x 16. Therefore in this timing computation, all values for P and Q (the array dimensions) are rounded up to the next higher power of 2. (i.e. 12 -> 16, 30 -> 32, etc.)

a. Window: the data is multiplied by a window function already residing in the AP-120B. It is assumed that an arbitrary window function may be loaded once and used for all temporal computations.

b. X Spatial Processing: A linear FFT is performed.

c. Y Spatial Processing: A 2-dimensional FFT is performed on the resultant linear FFT.

```
D = M * P * Q * T1                    (Window)
  + M * P * T1 * Q * log (Q)          (X spatial proc.)
  + M * 2 * Q * T1 * P * log (P)      (Y spatial proc.)
```

where: M = no. of spectral points
P = no. hydrophones along X dimension
Q = no. hydrophones along Y dimension
T1 = time/point/pass of FFT

and where log () is log base 2.

3.2.4 Transfer Data from the Array Processor to Memory -

This section describes the time necessary to transfer the FFT results from the AP-120B back to buffer memory. The type of data to be transferred is floating point complex. As a result of the zero filling (section 2.2, Fig. 4) used in the 2-dimensional FFT, 4 times the amount of data sent to the array processor is returned.

```
E = 4 * M * N2 * K2 / V
```

where: M = no. of spectral points
N2 = no. hydrophones (P & Q rounded up)
K2 = no. bytes/FFT cell
V = transfer rate Array processor to VAX

3.2.5 Averaging, Disk Read -

The following describes the time required to read spectrogram information off disk for averaging purposes. Spectrotram data is longword floating point and is assumed to be recovered off disk in a contiguous fashion. The data is arranged so that the first data point begins at the start of a track. It is always assumed that each frequency cell's block of wavenumber data occupies an integral number of tracks so that the next cell's data can start at the beginning of a track. Although this will use additional disk memory, it will tend to minimize the access time for the data. The time required to access the averaged data for a single frequency cell will require two disk revolutions for each track accessed plus a single average seek time to reach the first track.

The complex FFT data is converted to longword floating point notation prior to the magnitude-squared operation in order to preserve as much precision as possible. To understand the issue, consider that a normal floating point word has a 24 bit magnitude value. If the word represents voltage (amplitude), at 6db per bit, the word can represent a dynamic range of 144db. However, if the same floating point word is used to represent magnitude squared (power), then 24 bits is only 72db, since power is only 3db per bit. To maintain the full dynamic range, the magnitude squared values will be represented by longword floating point numbers. For ease of understanding, use is made of intermediate variables, U1, U2.

```
U1 = INT (4*(N2 - 1) * K2 / X) + 1    (no. Sectors/freq cell)
U2 = INT (U1 * M / (Q1 * H2))         (no. Cylinder switches)


F = ((U1 * R / Q1) + K3) * M          (raw data xfer time + one
                                       seek)
  + U2 * R                            (time for cylinder changes)
```

where: M = no. of spectral points
N2 = no. hydrophones (P & Q rounded up)
X = no. bytes/sector
K2 = no. bytes/frequency cell
K3 = average seek time
Q1 = no. of sectors / track
R = Time for one disk rotation
H2 = no. tracks/cylinder

3.2.6 Averaging, Computation Time -

This section describes the time it takes to perform the magnitude squared summation part of the averaging process. The example indicates the algorithm suggested to compute the magnitude square value for each point in the spatial FFT result and to average this data. This is performed for each cell selected from the temporal FFT for processing. What remains is a one time division to be performed at the end of the Spatial FFT process.

F1 = M * N2 * K4 * K5

where: M = no. of spectral points
N2 = no. hydrophones (P & Q rounded up)
K5 = floating point magnitude**2 time, taken to be 20 us, see example.
K4 = zero fill extensions, taken here to be 4

```
Ex:   LOOP:    Convert Real -> Double
               Convert Imag -> Double
               Double Real * Double Real
               Double Imag * Double Imag
               R**2 + I**2 = MAGSQ
               MAGSQ + AVE-> AVE
               DEC D1
               BNE LOOP
```

Here: R= real part
I= imaginary part
D1= counter (4 * N)

3.2.7 Averaging, Write Data to Disk -

This section describes the time required to write the current averaged spectrogram information from buffer memory back to disk. The data is longword floating point and is written to disk in a contiguous fashion. Note that during this write process an average seek time is not needed as the head is already in position. Although data transfer is contiguous, allowances must be made for occasional cylinder changes and the time for the head to move to an adjacent track if initially out of position. For ease of understanding, use is made of intermediate variables, U1, U2.

```
U1 = INT (4*(N2 - 1) * K2 / X) + 1    (no. Sectors/freq cell)
U2 = INT (U1 * M / (Q1 * H2))         (no. Cylinder switches)

C = (U1 * R / Q1) * M                 (raw data transfer time)
  + U2 * R                            (time for cylinder changes)
  + R * M                             (time to access data on
                                       adjacent track)
```

where: M = no. of spectral points
N2 = no. hydrophones (P & Q rounded up)
X = no. bytes/sector
K2 = no. bytes/frequency cell
Q1 = no. of sectors / track
R = time for one disk rotation
H2 = no. tracks/cylinder

3.2.8 Disk Space Requirements -

The following describes the additional disk space necessary for the averaging portion of the Spatial FFT procedure. For ease of understanding, use is made of the intermediate variable U1. The result is in bytes.

```
U1 = INT (4*(N2 - 1) * K2 / X) + 1    (no. Sectors/freq cell)

B2 = U1 * M * X
```

where: M = no. of spectral points
N2 = no. hydrophones (P & Q rounded up)
X = no. bytes/sector
K2 = no. bytes/frequency cell

3.2.9 Array Processor Storage Requirements -

The following is a description of the storage requirements of the AP-120B during Spatial FFT processing. The storage will vary as the number of hydrophones examined varies. The result is in bytes. The factor of 4 in the output spectrogram data is a storage requirement introduced by the 2-dimensional FFT.

```
S2 = N2 * K7 * 4      (output spectrogram data)
   + N2 * K7          (window)
```

where: N2 = no. hydrophones (P & Q rounded up)
K7 = no. bytes/floating point word

4.0 Recommendations

The data presented in this report is based on a preliminary software design for the frequency, wave-number processing. Data pre- and post-processing have not been addressed. For completeness, it is recommended that the following tasks be performed.

1. Perform a detailed design for the frequency, wave-number processing.

2. Perform a detailed design for the input data processing portion of the system. An important aspect of this design will be handling the problem of data corner turning.

3. Perform a detailed design for data post-processing. Such a design would address issues of display, data formatting, data reduction, etc.

4. Update the sizing study to reflect the results of the design efforts.

5.0 Appendix I

A BASIC program has been written to evaluate the equations associated with temporal processing. The number of temporal points processed per hydrophone is taken as 8192. This section contains projected timing results for the Temporal FFT process and memory requirements. The results are in tabular form and indicate analysis for each part of the Temporal FFT as discussed in section 3.1. They include specific breakdowns of times and memory requirements for several possible hydrophone array sizes.

```
10 REM DYNATRON CORP.  11/15/83
15 REM VAX3A/BAS
20 REM WRITTEN BY JAN DOLANSKY
30 REM THIS PROGRAM COMPUTES THE TIME INVOLVED TO COMPLETE
40 REM VARIOUS PARTS OF THE TEMPORAL FFT PROCESS.
50 REM
60 REM
70 REM CONSTANTS USED:
80 REM L= PROCESSING TIME TO PERFORM PRESORT OF ONE FREQUENCY
90 REM   CELL.
100 REM S= AMOUNT OF AVAILABLE RAM SPACE FOR DATA.
110 REM V= ARRAY PROCESSOR DATA TRANSFER RATE.
130 REM T1= TIME/POINT/PASS OF FFT.
131 REM R= WORST CASE DISK ROTATIONAL TIME
132 REM K3= AVERAGE SEEK TIME
133 REM Q1= # SECTORS/TRACK
134 REM X= # BYTES/SECTOR
135 REM K2= # BYTES/FFT CELL
136 REM K7= # BYTES TO TRANSFER/HYDROPHONE (BEFORE FFT)
137 REM K8= # BYTES TO TRANSFER/HYDROPHONE (AFTER FFT)
138 REM K9= # WORDS TO SORT/HYDROPHONE
139 REM H1= AVERAGE # OF ROTATIONS TO XFER 16KB (1.52871)
140 REM H2= TRACKS/CYLINDER
149 REM
150 REM VARIABLES:
160 REM P= LENGTH OF HYDROPHONE ARRAY.
170 REM Q= WIDTH OF ARRAY.
180 REM N= TOTAL NUMBER OF HYDROPHONES.
190 REM M= NUMBER OF SPECTRAL POINTS.
200 REM A1= DISK READ TIME, ALL DATA, CONTIGUOUS.
210 REM A2= TRANSFER TIME FROM MEMORY TO AP-120B
220 REM A3= FFT TIME.
230 REM A4= TRANSFER TIME FROM AP-120B TO MEMORY, REORDER.
240 REM A5= WRITE TIME FROM MEMORY TO DISK, CONTIGUOUS.
250 REM B1= DISK SPACE REQUIRED.
270 REM Z= TOTAL PROCESSING TIME.
276 REM S1= STORAGE SPACE REQUIRED OF AP-120B FOR TEMPORAL FFT
278 REM N1= # OF TIME SAMPLES/HYDROPHONE
279 REM Y1= # BUFFERS
280 REM Y2= # TRACKS/BUFFER
281 REM Y3= # CYLINDER BOUNDARIES
282 REM Y4= # OF DISK TRANSFER SETUPS
290 REM
295 REM
300 CMD"Z","ON"
310 PRINT "                    TEMPORAL FFT PROCESSING"
320 PRINT
330 PRINT
340 PRINT "P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY"
350 PRINT
360 PRINT "PLEASE INPUT P";
370 INPUT P
380 PRINT "PLEASE INPUT Q";
390 INPUT Q
```

```
410 L=.000005
430 V=1600000
450 PRINT
455 H1=1.52871
456 H2=19
460 N=P*Q
461 K2=8
462 S=2097152
463 Q1=22
464 X=512
465 R=.017
468 K3=.033
470 T1=.00000146
471 K7=16384
472 K8=32768
473 K9=K8/4
480 PRINT "# OF HYDROPHONES IS ";N
490 PRINT "PLEASE INPUT NUMBER OF SPECTRAL POINTS";
500 INPUT M
510 A1=N*((H1*R)+K3)
520 A2=N*K7/V
530 A3=N*T1*M*(LOG(M)/LOG(2))/2+(N*T1*M/2)+(N*T1*M/2)
540 A4=N*(K8/V+K9*L)
541 Y1=INT((N-1)*M*K2/S)+1
542 Y2=S/(Q1*X)
543 Y3=INT(Y1*Y2/H2)
544 Y4=Y1*(S/K8)
550 A5=Y1*Y2*R+Y3*R+K3*Y1+Y4*R
560 B1=INT((K2*M*(N-1)/S)+1)*S
562 N1=M*2
565 S1=N1*4+N1*2
570 PRINT "FFT TRASFER RATE OF ";V;" BYTES/SEC."
590 PRINT S;"BYTES OF AVAILABLE RAM SPACE."
600 PRINT
610 PRINT "READ TIME DATA OFF DISK=";TAB(25);A1;"SEC";TAB(43);A1/3600;"HOURS
620 PRINT "TRANSFER DATA TO AP-120B=";TAB(25);A2;"SEC";TAB(43);A2/3600;"HOUR
630 PRINT "PERFORM FFT=";TAB(25);A3;"SEC";TAB(43);A3/3600;"HOURS"
640 PRINT "WRITE TO MEM, REORDER=";TAB(25);A4;"SEC";TAB(43);A4/3600;"HOURS"
650 PRINT "WRITE TO DISK=";TAB(25);A5;"SEC";TAB(43);A5/3600;"HOURS"
660 Z=A1+A2+A3+A4+A5
670 PRINT
680 PRINT "THE WHOLE PROCESS WILL TAKE ";Z;" SEC. OR ";Z/3600;"HOURS."
690 PRINT:PRINT "TOTAL DISK REQUIREMENT, TEMPORAL FFT IS ";B1;"BYTES."
695 PRINT "TOTAL AP-120B STORAGE REQUIRED, TEMPORAL FFT IS ";S1;"BYTES."
700 CMD"Z","OFF"
710 LPRINT CHR$(13)
720 INPUT X9
730 IF X9 <> 0 THEN 710
740 GOTO 300
```

```
                    TEMPORAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 6
PLEASE INPUT Q? 6

# OF HYDROPHONES IS  36
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ TIME DATA OFF DISK=  2.12357 SEC        5.89881E-04 HOURS
TRANSFER DATA TO AP-120B= .36864 SEC         1.024E-04 HOURS
PERFORM FFT=              1.507 SEC          4.18611E-04 HOURS
WRITE TO MEM, REORDER=    2.21184 SEC        6.144E-04 HOURS
WRITE TO DISK=            4.43909 SEC        1.23308E-03 HOURS

THE WHOLE PROCESS WILL TAKE  10.6501  SEC.  OR  2.95837E-03 HOURS.

TOTAL DISK REQUIREMENT, TEMPORAL FFT IS  2.09715E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED, TEMPORAL FFT IS  49152 BYTES.



                    TEMPORAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 12
PLEASE INPUT Q? 12

# OF HYDROPHONES IS  144
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ TIME DATA OFF DISK=  8.49428 SEC        2.35952E-03 HOURS
TRANSFER DATA TO AP-120B= 1.47456 SEC        4.096E-04 HOURS
PERFORM FFT=              6.028 SEC          1.67444E-03 HOURS
WRITE TO MEM, REORDER=    8.84736 SEC        2.4576E-03 HOURS
WRITE TO DISK=            13.3513 SEC        3.70869E-03 HOURS

THE WHOLE PROCESS WILL TAKE  38.1955  SEC.  OR  .0106099 HOURS.

TOTAL DISK REQUIREMENT, TEMPORAL FFT IS  6.29146E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED, TEMPORAL FFT IS  49152 BYTES.
```

```
                    TEMPORAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 16

# OF HYDROPHONES IS  256
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ TIME DATA OFF DISK=  15.1009 SEC        4.19471E-03 HOURS
TRANSFER DATA TO AP-120B= 2.62144 SEC        7.28178E-04 HOURS
PERFORM FFT=              10.7164 SEC        2.97679E-03 HOURS
WRITE TO MEM, REORDER=    15.7286 SEC        4.36907E-03 HOURS
WRITE TO DISK=            17.8074 SEC        4.94649E-03 HOURS

THE WHOLE PROCESS WILL TAKE  61.9748  SEC.  OR  .0172152 HOURS.

TOTAL DISK REQUIREMENT, TEMPORAL FFT IS  8.38861E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED, TEMPORAL FFT IS  49152 BYTES.




                    TEMPORAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  512
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ TIME DATA OFF DISK=  30.2019 SEC        8.38941E-03 HOURS
TRANSFER DATA TO AP-120B= 5.24288 SEC        1.45636E-03 HOURS
PERFORM FFT=              21.4329 SEC        5.95358E-03 HOURS
WRITE TO MEM, REORDER=    31.4573 SEC        8.73813E-03 HOURS
WRITE TO DISK=            35.6147 SEC        9.89298E-03 HOURS

THE WHOLE PROCESS WILL TAKE  123.95  SEC.  OR  .0344305 HOURS.

TOTAL DISK REQUIREMENT, TEMPORAL FFT IS  1.67772E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED, TEMPORAL FFT IS  49152 BYTES.
```

6.0 Appendix II

A BASIC program has also been written for evaluation of the equations associated with spatial processing. This appendix contains estimated timing results and memory requirements for the Spatial process. The results are in tabular form, describing the value associated with each equation discussed in section 3.2. Although the temporal processing always generates 4096 frequency cells, it may be desirable to process only a portion of this data. Three sets of tables are presented. Computations have been performed for processing 1024, 2048 and 4096 temporal frequency cells. For each of the three values associated with the number of temporal points, several different values have been selected for P and Q, the number of hydrophones in the X and Y directions.

```
10 REM DYNATRON CORP.   11/15/83
20 REM VAX3B/BAS
30 REM WRITTEN BY JAN DOLANSKY
40 REM THIS PROGRAM COMPUTES THE TIME INVOLVED TO COMPLETE
50 REM VARIOUS PARTS OF THE SPATIAL FFT PROCESS.
60 REM
70 REM
80 REM CONSTANTS USED:
90 REM L= PROCESSING TIME TO PERFORM PRESORT OF ONE FREQUENCY
100 REM     CELL.
110 REM T= AMOUNT OF AVAILABLE RAM SPACE FOR DATA.
120 REM V= ARRAY PROCESSOR TRANSFER RATE.
130 REM T1= TIME/POINT/PASS OF FFT.
140 REM X= # BYTES/SECTOR
150 REM K3= AVERAGE SEEK TIEM
160 REM K4= # OF ZERO FILL EXTENSIONS
170 REM K2= # BYTES/FFT CELL
180 REM R= WORST CASE DISK ROTATIONAL TIME
190 REM K5= FLOATING POINT MAGNITUDE**2 EXECUTION TIME
200 REM Q1= # SECTORS/TRACK
210 REM K7= # BYTES/FLOATING POINT WORD
220 REM H2= # TRACKS/CYLINDER
230 REM
240 REM VARIABLES:
250 REM P= LENGTH IF HYDROPHONE ARRAY.
260 REM Q= WIDTH OF ARRAY.
270 REM M= TOTAL NUMBER OF SPECTRAL POINTS.
280 REM N= P * Q = # OF HYDROPHONES IN ARRAY.
290 REM B= READ DISK TIME, RANDOM ACCESS.
300 REM C= TRANSFER TIME, MEMORY TO AP-120B.
310 REM D= FFT TIME.
320 REM E= TRANSFER TIME, AP-120B TO MEMORY.
330 REM F= READ DISK TIME, RANDOM ACCESS, AVERAGING PROCESS.
340 REM F1= COMPUTATION TIME, AVERAGING PROCESS.
350 REM G= WRITE DISK TIME, RANDOM ACCESS, AVERAGING PROCESS.
360 REM S2= TOTAL AP-120B STORAGE REQUIREMENTS
370 REM B2= SPATIAL FFT DISK REQUIREMENTS
380 REM U1= # SECTORS/FREQUENCY CELL
390 REM U2= # CYLINDER SWITCHES
400 REM N2= # HYDROPHONES (USES ROUNDED UP P & Q)
410 REM
420 REM
430 CMD"Z","ON"
440 PRINT"                    SPATIAL FFT PROCESSING"
450 PRINT:PRINT
460 PRINT "P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY"
470 PRINT
480 PRINT "PLEASE INPUT P";
490 INPUT P
500 PRINT "PLEASE INPUT Q";
```

```
510 INPUT Q
520 L=.000005
530 H2=19
540 S=2097152
550 X=512
560 K3=.033
570 K4=4
580 K2=8
590 R=.017
600 Q1=22
610 K5=.00002
620 K7=4
630 V=1600000
640 PRINT
650 N=P*Q
660 T1=.00000146
670 PRINT "# OF HYDROPHONES IS ";N
680 PRINT "PLEASE INPUT NUMBER OF SPECTRAL POINTS";
690 INPUT M
700 GOSUB 1090
710 N2=P*Q
720 B=M*(INT((N-1)*K2/X)+1)*(K3+R/Q1)
730 C=M*N*K2/V
740 D=M*P*Q*T1+M*(P*T1*Q*(LOG (Q)/LOG(2))+2*Q*(T1*P*(LOG(P)/LOG(2))))
750 E=4*M*N2*K2/V
760 U1=INT(4*(N2-1)*K2/X)+1
770 U2=INT(U1*M/(Q1*H2))
780 F=((U1*R/Q1)+K3)*M+U2*R
790 G=(U1*R/Q1)*M+U2*R+R*M
800 B2=U1*M*X
810 S2=N2*K7*4+N2*K7
820 PRINT "FFT TRASFER RATE OF ";V;" BYTES/SEC."
830 PRINT S;"BYTES OF AVAILABLE RAM SPACE."
840 PRINT
850 PRINT "READ DISK,RANDOM ACCESS=";TAB(25);B;"SEC";TAB(43);B/3600;"HOURS
860 PRINT "TRANSFER MEM TO AP-120B=";TAB(25);C;"SEC";TAB(43);C/3600;"HOURS
870 PRINT "FFT TIME=";TAB(25);D;"SEC";TAB(43);D/3600;"HOURS"
880 PRINT "TRANSFER AP-120B TO MEM=";TAB(25);E;"SEC";TAB(43);E/3600;"HOURS
890 PRINT "AVERAGING, READ DISK=";TAB(25);F;"SEC";TAB(43);F/3600;"HOURS"
900 F1=M*N2*K4*K5
910 PRINT "AVERAGING, COMPUTATION=";TAB(25);F1;"SEC";TAB(43);F1/3600;"HOUR
920 PRINT "AVERAGING, WRITE DISK=";TAB(25);G;"SEC";TAB(43);G/3600;"HOURS"
930 Z=B+C+D+E+F+G+F1
940 PRINT
950 PRINT "THE WHOLE PROCESS WILL TAKE ";Z;"SEC OR ";Z/3600;"HOURS."
960 PRINT
970 PRINT "TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS ";B2;"BYTES."
980 PRINT"TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS ";S2;"BYTE
990 CMD"Z","OFF"
1000 LPRINT CHR$(13)
```

```
1010 INPUT X9
1020 IF X9 <> 0 THEN 1000
1030 GOTO 430
1040 REM
1050 REM
1060 REM THIS SUBROUTINE ROUNDS P AND Q UP TO THE NEXT
1070 REM LOGARITHMS RETURNED ARE ROUNDED UP TO THE NEXT INTEGER
1080 REM HIGHEST POWER OF 2
1090 Z1=Q
1100 GOSUB 1200
1110 IF J=INT(J) THEN 1140
1120 J=INT(J+1)
1130 Q=2[J
1140 Z1=P
1150 GOSUB 1200
1160 IF J=INT(J) THEN 1190
1170 J=INT(J+1)
1180 P=2[J
1190 RETURN
1200 J = LOG(Z1)/LOG(2)
1210 RETURN
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 6
PLEASE INPUT Q? 6

# OF HYDROPHONES IS  36
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 1024
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  34.5833 SEC        9.60646E-03 HOURS
TRANSFER MEM TO AP-120B=  .18432 SEC         5.12E-05 HOURS
FFT TIME=                 .956826 SEC        2.65785E-04 HOURS
TRANSFER AP-120B TO MEM=  1.31072 SEC        3.64089E-04 HOURS
AVERAGING, READ DISK=     37.1101 SEC        .0103084 HOURS
AVERAGING, COMPUTATION=   5.24288 SEC        1.45636E-03 HOURS
AVERAGING, WRITE DISK=    20.7261 SEC        5.75725E-03 HOURS

THE WHOLE PROCESS WILL TAKE  100.114 SEC OR  .0278095 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  2.09715E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  1280. BYTES.



                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 12
PLEASE INPUT Q? 12

# OF HYDROPHONES IS  144
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 1024
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  103.75 SEC         .0288194 HOURS
TRANSFER MEM TO AP-120B=  .73728 SEC         2.048E-04 HOURS
FFT TIME=                 4.97549 SEC        1.38208E-03 HOURS
TRANSFER AP-120B TO MEM=  5.24288 SEC        1.45636E-03 HOURS
AVERAGING, READ DISK=     47.1154 SEC        .0130876 HOURS
AVERAGING, COMPUTATION=   20.9715 SEC        5.82542E-03 HOURS
AVERAGING, WRITE DISK=    30.7314 SEC        8.53649E-03 HOURS

THE WHOLE PROCESS WILL TAKE  213.524 SEC OR  .0593122 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  8.38861E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 16

# OF HYDROPHONES IS  256
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 1024
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  138.333 SEC        .0384259 HOURS
TRANSFER MEM TO AP-120B=  1.31072 SEC        3.64089E-04 HOURS
FFT TIME=                 4.97549 SEC        1.38208E-03 HOURS
TRANSFER AP-120B TO MEM=  5.24288 SEC        1.45636E-03 HOURS
AVERAGING, READ DISK=     47.1154 SEC        .0130876 HOURS
AVERAGING, COMPUTATION=   20.9715 SEC        5.82542E-03 HOURS
AVERAGING, WRITE DISK=    30.7314 SEC        8.53649E-03 HOURS

THE WHOLE PROCESS WILL TAKE  248.68 SEC OR  .0690779 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  8.38861E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.



                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  512
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 1024
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  276.666 SEC        .0768517 HOURS
TRANSFER MEM TO AP-120B=  2.62144 SEC        7.28178E-04 HOURS
FFT TIME=                 10.7164 SEC        2.97679E-03 HOURS
TRANSFER AP-120B TO MEM=  10.4858 SEC        2.91271E-03 HOURS
AVERAGING, READ DISK=     60.4387 SEC        .0167885 HOURS
AVERAGING, COMPUTATION=   41.943 SEC         .0116508 HOURS
AVERAGING, WRITE DISK=    44.0547 SEC        .0122374 HOURS

THE WHOLE PROCESS WILL TAKE  446.926 SEC OR  .124146 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  1.67772E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  10240 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 32
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  1024
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 1024
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=   553.332 SEC        .153703 HOURS
TRANSFER MEM TO AP-120B=   5.24288 SEC        1.45636E-03 HOURS
FFT TIME=                  24.4947 SEC        6.80409E-03 HOURS
TRANSFER AP-120B TO MEM=   20.9715 SEC        5.82542E-03 HOURS
AVERAGING, READ DISK=      87.0855 SEC        .0241904 HOURS
AVERAGING, COMPUTATION=    83.8861 SEC        .0233017 HOURS
AVERAGING, WRITE DISK=     70.7015 SEC        .0196393 HOURS

THE WHOLE PROCESS WILL TAKE  845.714 SEC OR  .234921 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  3.35544E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  20480 BYTES.



                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 6
PLEASE INPUT Q? 6

# OF HYDROPHONES IS  36
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 2048
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=   69.1666 SEC        .0192129 HOURS
TRANSFER MEM TO AP-120B=   .36864 SEC         1.024E-04 HOURS
FFT TIME=                  1.91365 SEC        5.3157E-04 HOURS
TRANSFER AP-120B TO MEM=   2.62144 SEC        7.28178E-04 HOURS
AVERAGING, READ DISK=      74.2372 SEC        .0206214 HOURS
AVERAGING, COMPUTATION=    10.4858 SEC        2.91271E-03 HOURS
AVERAGING, WRITE DISK=     41.4692 SEC        .0115192 HOURS

THE WHOLE PROCESS WILL TAKE  200.262 SEC OR  .0556284 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  4.1943E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  1280 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 12
PLEASE INPUT Q? 12

# OF HYDROPHONES IS  144
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 2048
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  207.5 SEC          .0576388 HOURS
TRANSFER MEM TO AP-120B=  1.47456 SEC        4.096E-04 HOURS
FFT TIME=                 9.95099 SEC        2.76416E-03 HOURS
TRANSFER AP-120B TO MEM=  10.4858 SEC        2.91271E-03 HOURS
AVERAGING, READ DISK=     94.2307 SEC        .0261752 HOURS
AVERAGING, COMPUTATION=   41.943 SEC         .0116508 HOURS
AVERAGING, WRITE DISK=    61.4627 SEC        .017073 HOURS

THE WHOLE PROCESS WILL TAKE  427.047 SEC OR  .118624 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  1.67772E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.



                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 16

# OF HYDROPHONES IS  256
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 2048
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  276.666 SEC        .0768517 HOURS
TRANSFER MEM TO AP-120B=  2.62144 SEC        7.28178E-04 HOURS
FFT TIME=                 9.95099 SEC        2.76416E-03 HOURS
TRANSFER AP-120B TO MEM=  10.4858 SEC        2.91271E-03 HOURS
AVERAGING, READ DISK=     94.2307 SEC        .0261752 HOURS
AVERAGING, COMPUTATION=   41.943 SEC         .0116508 HOURS
AVERAGING, WRITE DISK=    61.4627 SEC        .017073 HOURS

THE WHOLE PROCESS WILL TAKE  497.361 SEC OR  .138156 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  1.67772E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  512
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 2048
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  553.332 SEC        .153703 HOURS
TRANSFER MEM TO AP-120B=  5.24288 SEC        1.45636E-03 HOURS
FFT TIME=                 21.4329 SEC        5.95358E-03 HOURS
TRANSFER AP-120B TO MEM=  20.9715 SEC        5.82542E-03 HOURS
AVERAGING, READ DISK=     120.877 SEC        .0335771 HOURS
AVERAGING, COMPUTATION=   83.8861 SEC        .0233017 HOURS
AVERAGING, WRITE DISK=    88.1095 SEC        .0244749 HOURS

THE WHOLE PROCESS WILL TAKE  893.853 SEC OR  .248292 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  3.35544E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  10240 BYTES.




                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 32
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  1024
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 2048
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  1106.66 SEC        .307407 HOURS
TRANSFER MEM TO AP-120B=  10.4858 SEC        2.91271E-03 HOURS
FFT TIME=                 48.9895 SEC        .0136082 HOURS
TRANSFER AP-120B TO MEM=  41.943 SEC         .0116508 HOURS
AVERAGING, READ DISK=     174.188 SEC        .0483855 HOURS
AVERAGING, COMPUTATION=   167.772 SEC        .0466034 HOURS
AVERAGING, WRITE DISK=    141.42 SEC         .0392833 HOURS

THE WHOLE PROCESS WILL TAKE  1691.46 SEC OR  .469851 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  6.71089E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  20480 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 6
PLEASE INPUT Q? 6

# OF HYDROPHONES IS  36
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=   138.333 SEC        .0384259 HOURS
TRANSFER MEM TO AP-120B=   .73728 SEC         2.048E-04 HOURS
FFT TIME=                  3.8273 SEC         1.06314E-03 HOURS
TRANSFER AP-120B TO MEM=   5.24288 SEC        1.45636E-03 HOURS
AVERAGING, READ DISK=      148.491 SEC        .0412476 HOURS
AVERAGING, COMPUTATION=    20.9715 SEC        5.82542E-03 HOURS
AVERAGING, WRITE DISK=     82.9554 SEC        .0230432 HOURS

THE WHOLE PROCESS WILL TAKE  400.559 SEC OR  .111266 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  8.38861E+06 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  1280 BYTES.




                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 12
PLEASE INPUT Q? 12

# OF HYDROPHONES IS  144
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=   414.999 SEC        .115278 HOURS
TRANSFER MEM TO AP-120B=   2.94912 SEC        8.192E-04 HOURS
FFT TIME=                  19.902 SEC         5.52833E-03 HOURS
TRANSFER AP-120B TO MEM=   20.9715 SEC        5.82542E-03 HOURS
AVERAGING, READ DISK=      188.461 SEC        .0523504 HOURS
AVERAGING, COMPUTATION=    83.8861 SEC        .0233017 HOURS
AVERAGING, WRITE DISK=     122.925 SEC        .034146 HOURS

THE WHOLE PROCESS WILL TAKE  854.095 SEC OR  .237249 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  3.35544E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.
```

```
                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 16

# OF HYDROPHONES IS  256
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  553.332 SEC        .153703 HOURS
TRANSFER MEM TO AP-120B=  5.24288 SEC        1.45636E-03 HOURS
FFT TIME=                 19.902 SEC         5.52833E-03 HOURS
TRANSFER AP-120B TO MEM=  20.9715 SEC        5.82542E-03 HOURS
AVERAGING, READ DISK=     188.461 SEC        .0523504 HOURS
AVERAGING, COMPUTATION=   83.8861 SEC        .0233017 HOURS
AVERAGING, WRITE DISK=    122.925 SEC        .034146 HOURS

THE WHOLE PROCESS WILL TAKE  994.722 SEC OR  .276312 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  3.35544E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  5120 BYTES.



                    SPATIAL FFT PROCESSING


P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 16
PLEASE INPUT Q? 32

# OF HYDROPHONES IS  512
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF  1.6E+06  BYTES/SEC.
 2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK,RANDOM ACCESS=  1106.66 SEC        .307407 HOURS
TRANSFER MEM TO AP-120B=  10.4858 SEC        2.91271E-03 HOURS
FFT TIME=                 42.8658 SEC        .0119072 HOURS
TRANSFER AP-120B TO MEM=  41.943 SEC         .0116508 HOURS
AVERAGING, READ DISK=     241.772 SEC        .0671589 HOURS
AVERAGING, COMPUTATION=   167.772 SEC        .0466034 HOURS
AVERAGING, WRITE DISK=    176.236 SEC        .0489544 HOURS

THE WHOLE PROCESS WILL TAKE  1787.74 SEC OR  .496594 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS  6.71089E+07 BYTES.
TOTAL AP-120B STORAGE REQUIRED,SPATIAL FFT PROCESS IS  10240 BYTES.
```

SPATIAL FFT PROCESSING

P = LENGTH OF HYDROPHONE ARRAY, Q = WIDTH OF ARRAY

PLEASE INPUT P? 32
PLEASE INPUT Q? 32

OF HYDROPHONES IS 1024
PLEASE INPUT NUMBER OF SPECTRAL POINTS? 4096
FFT TRASFER RATE OF 1.6E+06 BYTES/SEC.
2.09715E+06 BYTES OF AVAILABLE RAM SPACE.

READ DISK, RANDOM ACCESS=	2213.33 SEC	.614814 HOURS
TRANSFER MEM TO AP-120B=	20.9715 SEC	5.82542E-03 HOURS
FFT TIME=	97.9789 SEC	.0272164 HOURS
TRANSFER AP-120B TO MEM=	83.8861 SEC	.0233017 HOURS
AVERAGING, READ DISK=	348.393 SEC	.0967758 HOURS
AVERAGING, COMPUTATION=	335.544 SEC	.0932068 HOURS
AVERAGING, WRITE DISK=	282.857 SEC	.0785713 HOURS

THE WHOLE PROCESS WILL TAKE 3382.96 SEC OR .939711 HOURS.

TOTAL DISK REQUIREMENT, SPATIAL FFT PROCESS IS 1.34218E+08 BYTES.
TOTAL AP-120B STORAGE REQUIRED, SPATIAL FFT PROCESS IS 20480 BYTES.